

BELLCOMM, INC. A

SUBJECT: 3 Review of SIVB Stage Emergency
Detection System at Douglas
Aircraft Corp., Huntington
Beach, August 16 - Case 330

DATE: 9 October 5, 1966

FROM: 6 T. F. Loeffler

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ABSTRACT

A review of the implementation of the Apollo Saturn Emergency Detection System (EDS) in the SIVB stage was held by representatives of MSC, MSFC, Douglas Aircraft, NAA, and MAS/Bellcomm at the Douglas Aircraft facility in Huntington Beach, California, on August 16, 1966. This memorandum serves as the minutes of the meeting.

Formal presentations covered design philosophy, implementation, major components, and problem areas. Questions, discussions, and observations of the EDS Review Team were focused upon areas where single point failures could cause any trouble; special attention was directed toward the implementation of the electrical/mechanical design, after a problem of mechanical non-redundancy of redundant electrical functions became evident. In addition, the general philosophy of checkout, inspection and test procedures was discussed.

As a result of this meeting, it was found that mechanically non-redundant connectors, cables, and other components represent single failure points of (redundant) electrical EDS functions in a number of places on this stage. The EDS Review Team will recommend mandatory changes of at least the "Engine Cutoff Command" leads routing for AS-204 and subsequent. An MSFC action item has been generated, and a resulting request for ECP's has been sent to the contractors.

Other (minor) problem areas of pressure transducer drop-outs, and transducer calibration fragility are currently under study and testing respectively.

Inspection of boosters No. 502 and 208 indicated generally good cabling layout and wiring quality. With the exception of the previously mentioned non-redundancy, the implementation of SIVB EDS left a good impression with the EDS Review Team.

(NASA-CR-153832) REVIEW OF SIVB STAGE
EMERGENCY DETECTION SYSTEM AT DOUGLAS
AIRCRAFT CORP., HUNTINGTON BEACH, 16 AUGUST
(Bellcomm, Inc.) 23 p

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MEMORANDUM FOR FILE

A review of the implementation of the Apollo Saturn Emergency Detection System (EDS) in the SIVB stage was held by representatives of MSC, MSFC, Douglas Aircraft, NAA, and MAS/Bellcomm at the Douglas Aircraft facility in Huntington Beach, California, on August 16, 1966. This memorandum serves as the minutes of the meeting. The list of attendees is given in Appendix A. This meeting was the third one of the EDS implementation reviews that were initiated at the request of the EDS subpanel of the Apollo Saturn Electrical Panel. The first and second reviews covered the CSM* and the SIB** portions of EDS respectively.

Because of the critical interdependence of EDS circuitry and components in various stages of the space vehicle, this set of reviews is intended to cover the EDS, and related items of interest in the Saturn IB vehicle stages and Block I CSM's, with the basic objectives of:

1. Insuring that the implementation of the integrated EDS properly supports the design objectives of the system, as expressed by intercenter panel document.
2. Verifying that the checkout of the entire EDS is adequate to establish readiness for flight.

Mr. R. J. Bryson, of the Saturn Branch Chief Office, DAC, opened the meeting with introductions, and the agenda for the meeting. Subsequently, a four-part presentation of EDS design implementation was given by Messrs. G. D. Bartelmie, L. A. Zakian, D. W. Pearson, L. P. Morata, C. R. Rubenstein, E. W. Ryall and

*Review of CSM Emergency Detection System at NAA on July 28, T. F. Loeffler, memorandum for file dated August 17, 1966

**Review of SIB Emergency Detection System at Chrysler-Michoud on August 20, 1966, T. F. Loeffler, memorandum for file dated August 28, 1966

J. L. Holmgren of SIVB Stage Design, DAC. After this, Mr. B. C. Adams of SIVB System Design, DAC, covered SIVB stage checkout. Flip charts of the presentations are attached in Appendix B.

Items covered during and after these presentations were as follows:

1. SIVB EDS implementation and design philosophy of the three primary SIVB EDS functions: tank (ullage) pressure measurements, main-stage (thrust) OK pressure, and (J-2) engine cut-off (see Figures 1 through 5).
2. Discussion of major elements, their diagrams, schematics and pictures, including a display of a number of actual components (potted modules, etc.). During the discussion it was noted that the EDS engine cut-off commands were coming from the same diode module (P/N 40604 on Figures 1 and 2); subsequent questioning revealed that mechanical non-redundancy of electrical components, and connectors exist in a number of places in the SIVB stage. In order to alleviate this problem, an action item to MSFC was generated. This problem was again discussed after the hardware inspection; at that time it was agreed, that the EDS review team will recommend a mandatory modification to the Apollo Saturn Electrical Panel (ASEP) for changing at least the "Engine Cut Off" command leads to two separate modules and connectors for AS-204 and subsequent. Also, it was indicated that the contractors will receive a request to assess the extent and the impact upon AS-204 of the modifications necessary to alleviate similar conditions in the launch vehicle stage(s).
3. Equipment locations, and cabling installations (see Figures 6 through 8, Appendix B.)
4. Test results, problem areas, problem causes (if found) and the method of correcting them: These items included items such as: relay module problem, caused by leaky diode; momentary (non-simultaneous) dropouts of pressure transducers at shut-down, cause unknown; fragility of transducer calibrations, redesign of installation is in qualification tests at present.
5. Scaling of fuel and LOX tank pressure measurements in SIVB: This item is further discussed in Appendix B.

6. EDS subsystem checkout requirements: DAC indicated that the set of tests performed are as follows:
 - a. Verification of wiring compatibility for all wiring from S-IVB-SIB Interfaces through to the S-IVB/IU Interfaces, that cannot be verified functionally.
 - b. Verification of functional operation of:
 1. LOX Tank Ullage Pressure Transducers 1 and 2
 2. LH₂ Tank Ullage Pressure Transducers 1 and 2
 3. S-IVB Thrust OK 1 and 2
 4. EDS Engine Cutoff 1 and 2
 5. 4D11 (Aft Bus 1) and 4D31 (Fwd Bus 1) Bus Voltages as Bi-levels to the IU
 6. Range Safety 1 and 2 Engine Cut-off indications to the IU.

During the afternoon the "Vertical Checkout" building was visited. In this area SIVB's No. 503 and No. 208 were shown under different stages of checkout and testing. Mr. Zakian of DAC explained cable routing, etc., on these stages. All EDS components and cables were tagged for ease of identification during the inspection. The EDS items of interest discussed earlier were pointed out, and discussed with the EDS review team.

In conclusion, Messrs. A. Dennett/MSFC, W. Shields/MSFC, H. Pringle/NAA, and the author reviewed the highlights of the meeting which are summarized below.

SUMMARY

Mechanical non-redundancy of (redundant) electrical components, connectors, etc., exists in a number of places on the SIVB stage, as described earlier. An MSFC action item has been generated to correct this problem. A recommendation will be made to ASEP for mandatory change of at least the Engine Cut Off Command leads' routing for AS-204 (and subsequent). A request for assessment of the extent and impact upon AS-204 of modifications in the launch vehicle stage(s) has been sent to the respective contractors via normal channels.

Discussion of problem areas during the meeting and the inspection of the hardware revealed no other significant problems. The minor problems of momentary pressure transducer dropouts are currently under study; the redesigned transducer installation (to solve calibration fragility problem) is presently in qualification testing. Cabling layout and wiring quality was in general quite good.

The presentation was excellent, the handouts (attached in Appendix B) augmented the presentation well, and the identifying marks on EDS components on the stage in the VCO building aided the visual inspection significantly. The Douglas team was praised for their performance of the SIVB EDS Review presentation.

2031-TFL-sam

T. F. Loeffler

Attachments
Appendix A-B

Copy to

Messrs. L. E. Day - NASA/MAT
J. K. Holcomb - NASA/MAO
T. A. Keegan - NASA/MA-2
M. L. Seccomb - NASA/MAP
J. H. Turnock - NASA/MA-4
W. J. Willoughby - NASA/MAR

A. Cohen - MSC/PD4
A. Dennett - MSC/PD4
E. B. Hamblett - MSC/PD2
S. C. Jones - MSC/PD4

H. J. Fichtner - MSFC/R-ASTR-E
W. G. Shields - MSFC/R-ASTR-E
F. E. Vreuls - MSFC/I-I/IB-B
L. C. Wood - MSFC/R-ASTR-E

D. C. Moja - KSC/LV-22

C. Bidgood
D. R. Hagner
W. C. Hittinger
B. T. Howard
P. R. Knaff
J. Z. Menard
I. D. Nehama
T. L. Powers
M. M. Purdy
I. M. Ross
T. H. Thompson
G. B. Trousoff
R. L. Wagner

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BELLCOMM, INC.

APPENDIX A

List of attendees at the SIVB EDS Review Meeting on August 16, 1966,
at Douglas Aircraft Company, Huntington Beach, California:

<u>NAME</u>	<u>ORGANIZATION</u>
J. D. Shields	DAC - Stage Design
L. A. Zakian	DAC - Stage Design
L. P. Morata	DAC - Stage Design
G. D. Bartelmie	DAC - Stage Design
D. W. Pearson	DAC - Stage Design
E. W. Ryall	DAC - Stage Design
J. L. Holmgren	DAC - Stage Design
J. W. Finney	DAC - TP&E Electronics
R. J. Bryson	DAC - Electronics
E. L. Wilson	DAC - Design Office
C. R. Rubenstein	DAC - Instrumentation
J. D. Bloom	DAC - Instrumentation
M. J. Mohrhauser	DAC - System Design
B. C. Adams	DAC - System Design
L. N. Shelton	DAC - Operations Support
W. J. Vellutini	DAC - Propulsion
R. G. Logston	DAC - VCL
P. M. Turbitt	DAC - Reliability
W. L. Paulson	DAC - Systems Engineering
H. Pringle	North American - S&ID
T. F. Loeffler	MSF/MAS - Bellcomm
W. G. Shields	NASA/MSFC
K. P. Oldenburger	DAC - A45 Project
J. Kenney	NASA/MSFC
A. Dennett	MSC/NASA-Houston
M. Davis	NASA/MSFC
O. W. Sturtevant	NASA/Resident Office
R. M. Lewis	NASA-R/QUAL/P
D. C. Scharlach	NASA-R/QUAL/P/GE

SATURN S-IVB EMERGENCY DETECTION SYSTEM

System Description

The EDS system as related to the S-IVB Stage is broken into three distinct functions: (1) Tank pressure measurements, (2) Mainstage OK pressure, (3) J-2 engine cutoff. The design philosophy used in implementing the EDS system required that all functions be redundant and also be powered by redundant sources.

The EDS (Tank pressure measurements system) is comprised of two 5-volt transducers for both the LOX and fuel tanks. There is a current limit resistor in the power and control leg of each transducer. The output of these transducers are terminated at the IU interface and also paralleled off to the S-IVB T/M system. These measurements are defined as flight control on Vehicle 2005 and subs and Vehicle 1005 and subs.

The EDS mainstage OK indications are used to activate two relays in the S-IVB sequencer. The output of these two pressure switches on the J-2 engine are also monitored on the S-IVB telemetry system through 10K isolation resistors. Actuation of the two relays in the sequencer breaks the power source to the IU interface. These power sources are made up of redundant supplies plus 6D91 and plus 6D92 from the IU.

EDS cutoff circuitry involves the capability of the IU transmitting cutoff to the S-IVB Stage by the means of EDS No. 1 and No. 2. These commands are also made up by separate power sources and are isolated by blocking diodes located in the sequencer on the S-IVB Stage. The initiation of either of these commands will transmit cutoff to the J-2 engine and also close the S-IVB prevalues through the time delay timer. The other circuit associated with engine cutoff and EDS is the initiation of the Range Safety controllers #1 and #2. The activation of either controller will send a command to the IU interface. The Range Safety controllers are powered by separate power sources, and their outputs activate a relay which transmits a signal from redundant power sources, plus 6D91 for Range Safety #1 and plus 6D92 for Range Safety #2, to the IU interface.

The emergency detection system was designed to requirements established by NASA/MSFC. The following list details the contract authority for the design and implementation:

<u>Contract Authority</u>	<u>Effectivity</u>	<u>Title</u>
C/O 214	201-212	Implementation of EDS for S-IVB/IB
C/O 265	501-506	Implementation of EDS for S-IVB/V
C/O 482	204-212 503-506	Independent excitation for EDS Power Supply

<u>Contract Authority</u>	<u>Effectivity</u>	<u>Title</u>
C/O 658	202-	Revision to Engine thrust OK Circuits
I-CO-SD-L-957	204-212	
	501-506	
C/O 460	204-212	Redundant EDS eng. Start circuit through S-IVB/S-1B Interface.
C/O 813		
I-CO-S-IVB-6-198	203-212	Modification of EDS Engine cutoff Circuits.
I-CO-S-IVB-6-315	501-506	
I-CO-S-IVB-6-338		

Component Description

The primary components within the EDS are the sequencer, forward and aft power distributors, pressure transducers, and 5 volt excitation module. In addition, there are various relay modules, diode modules, and resistor modules used also. The following is a detailed list of components:

10 Amp Relay Module (P/N 1A74218)

The 10 amp relay module is an encapsulated module consisting of four conventional relays. Each relay has a suppression diode and resistor in addition to test points and T/M monitoring points. This module is used.

Diode Module (P/N 1B40604)

This module is an encapsulated module consisting of 9-1N649 diodes. These diodes are used for isolating signals and power sources.

Resistor Module (P/N 1A79673)

The resistor module is an encapsulated module consisting of 12 -10K ohm resistors. The resistors are used for isolating indications to the T/M system.

Resistor Module (P/N 1B40464)

This resistor module is an encapsulated module designed to provide 250 ohm isolation in each leg of the EDS ullage pressure measurements.

Distribution Module (P/N 1A97868)

The distribution module is a bussed module consisting of 13 sets of four pin busses and 1 three pin buss. It is used for signal and measurement distribution.

5 Volt Excitation Module (P/N 1A77310)

The 5 volt excitation module is a transistorized power conversion module which transforms 28 vdc to +5 vdc -20 vdc and four 10 volt peak-to-peak square waves at 2000 cps.

The -20 vdc is used for telemetry signal conditioning and the 2000 cps signal is used in the batteries.

The +5 vdc is used to supply excitation to the EDS ullage pressure measurements.

Sequencer (P/N 1B39550)

The sequencer provides the logic circuitry needed to control and operate all of the vehicle subsystems which require flight sequencing. The sequencer receives program timed commands from the instrument unit via the stage mounted switch selector. The sequencer also receives inputs from pressure switches propellant level sensors, range safety system, EDS logic within the IU.

28 Volt Aft Power Distribution Assembly (P/N 1B51354)

The aft 28 v power distribution assembly is used to distribute power from 28 volt aft battery #1 to the stage, IU and the lower stage. It also serves as a junction box for wiring in the aft skirt area and the EDS LOX ullage pressure measurements.

Forward Power Distribution Assembly (P/N 1B51379)

The forward power distribution assembly is used to distribute power from forward battery #1, #2 to the range safety system, 5 volt excitation modules, and IU. It also serves as a junction box for the EDS LH₂ ullage pressure measurements.

Pressure Transducer(P/N 1B43324)

This is a potentiometer type pressure transducer used for monitoring the LOX and Fuel Tank ullage pressure.

EDS MEASUREMENTS

The EDS Measurements on the S-IVB Stage are redundant Fuel and LOX Tank Pressure Measurements, D177 thru D180.

Range 0 to 50 psia

Transducers 1A68551-545 Vehicles 201, 202

1B43320-601 Vehicles 203 - 212, 501 - 506 (D177, D178)

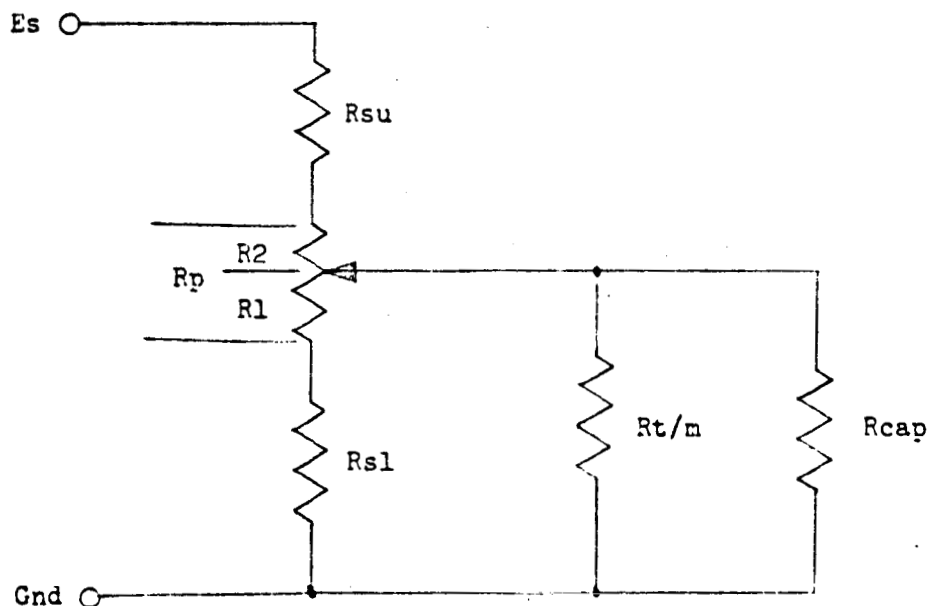
1B43324-601 Vehicles 203 - 212, 501 - 506 (D179, D180)

The transducer was changed at Vehicle 203 since the transducer basically was an oil damped designed unit with the oil removed for LOX compatibility which caused the unit to be vibration susceptible. The new transducer is a "dry" unit with improved vibration characteristics.

The transducer is calibrated with a 2 megohm load and without end resistors which are separately mounted. The maximum error of 0.037% of full scale results due to loading but these data are used as the open circuit calibration points. The test equipment has an accuracy of 0.29%.

The actual vehicle circuit consists of 2 separate excitation sources. Each source excites one transducer in both the LOX and fuel tanks for complete redundancy.

Typical vehicle circuit for each measurement:



Derivation for load effects:

$E_s = 5v$ excitation $\pm 0.5\%$ under all environments

R_{su} = Upper series resistance, 250 ohms $\pm 1\%$

R_{sl} = Lower series resistance, 250 ohms $\pm 1\%$

R_p = Potentiometer resistance 5,000 ± 250 ohms

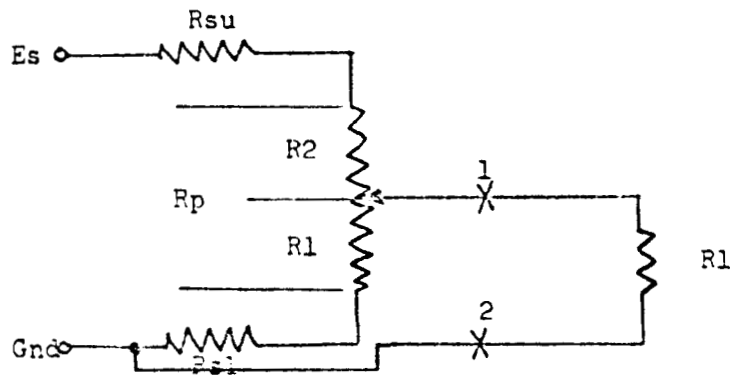
$R_{t/m}$ = Telemetry load resistance, 100k ohms $\pm 1\%$

R_{cap} = Capsule load resistance,

E_c = Calibration Voltage Ration, $\frac{R_1}{R_1 + R_2} = \frac{R_1}{R_p}$

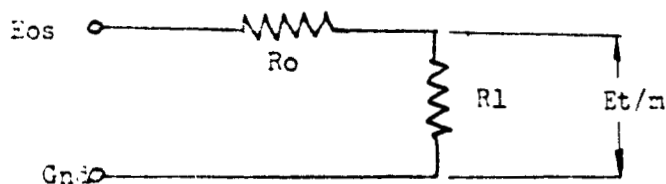
$$\frac{(R_{t/m})(R_{cap})}{R_{tm} + R_{cap}} = R_1$$

EFFECTIVE CIRCUIT



$$E_{os(1-2)} = \frac{E_s (R_{sl} + R_1)}{R_p + R_{su} + R_{sl}} = \frac{E_s (R_{sl} + E_c R_p)}{R_p + R_{su} + R_{sl}}$$

$$R_o (1-2) = \frac{(R_1 + R_{sl})(R_2 + R_{su})}{R_p + R_{su} + R_{sl}} = \frac{(E_c R_p + R_{sl})(R_p - E_c R_p + R_{su})}{R_p + R_{su} + R_{sl}}$$



$$E_{t/m} = \frac{E_{os} R_1}{R_o + R_1} = \frac{\frac{E_s (R_{sl} + E_c R_p)(R_1)}{R_p + R_{su} + R_{sl}}}{\frac{(E_c R_p + R_{sl})(R_p - E_c R_p + R_{su})}{R_p + R_{su} + R_{sl}} + R_1} + R_1$$

Simplify and Collect Terms

$$\frac{E_{tm}}{E_s} = \frac{(R_{s1} + E_c R_p) R_l}{E_c R_p (R_p + R_{su} - R_{s1}) - E_c^2 R_p^2 + R_l (R_p + R_{su} + R_{s1}) + R_{s1} (R_p + R_{su})}$$

The actual measured value ($\pm .03\%$) during receiving test is used for the value of R_p to eliminate the approximate 0.5% change in voltage drop across the series potentiometer trim resistors.

From the final equation, data points of $\frac{E_{tm}}{E_s}$ is calculated and curve fit to a binomial expansion. This curve becomes part of the calibration data and the potentiometer calibration data points are modified to obtain a telemetry voltage verses pressure curve for flight data reduction.

Present Loading Information on Capsule

Vehicles 204, 205, 206 - ~~25k ohms~~

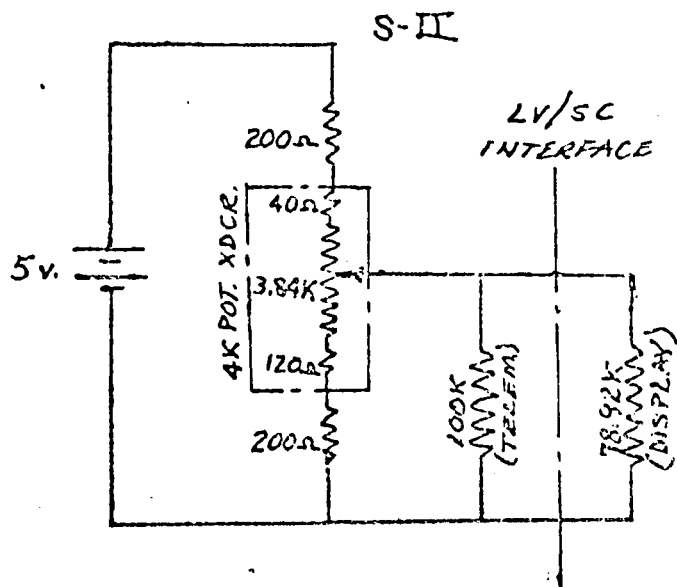
Vehicles 501, 502 - 25k ohms

Vehicle 207 & subs - 78.92k ohms

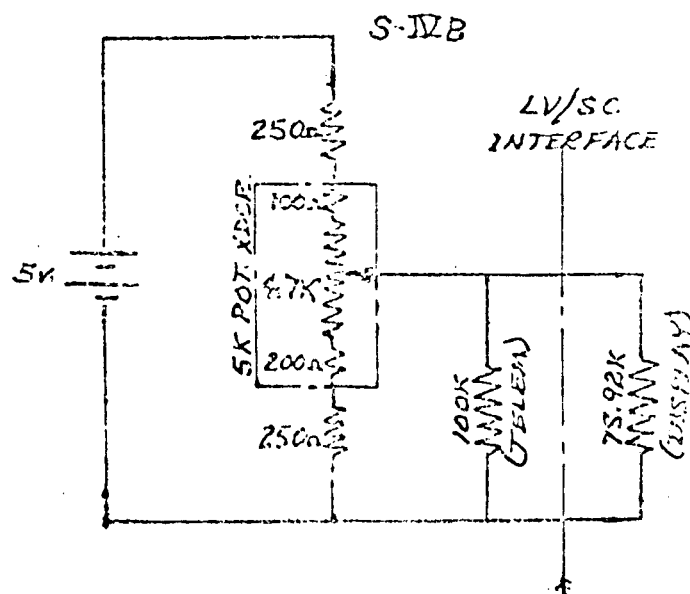
Vehicle 503 & subs - 78.92k ohms

Assumption - There is no switching of load in capsule during flight.

The following are the circuits for the EDS pressure transducers for the S-II and S-IVB stages (effective on AS-207, AS-503, and subs) and the resultant interface signal characteristics.

S-II

Voltage Range	0-5 volts
Source Impedance	1088 ohms (maximum)
Load Impedance	78,920 ohms
Zero Offset	0.362 volts
Scale Factor	0.08684 volts per psi

S-IVB

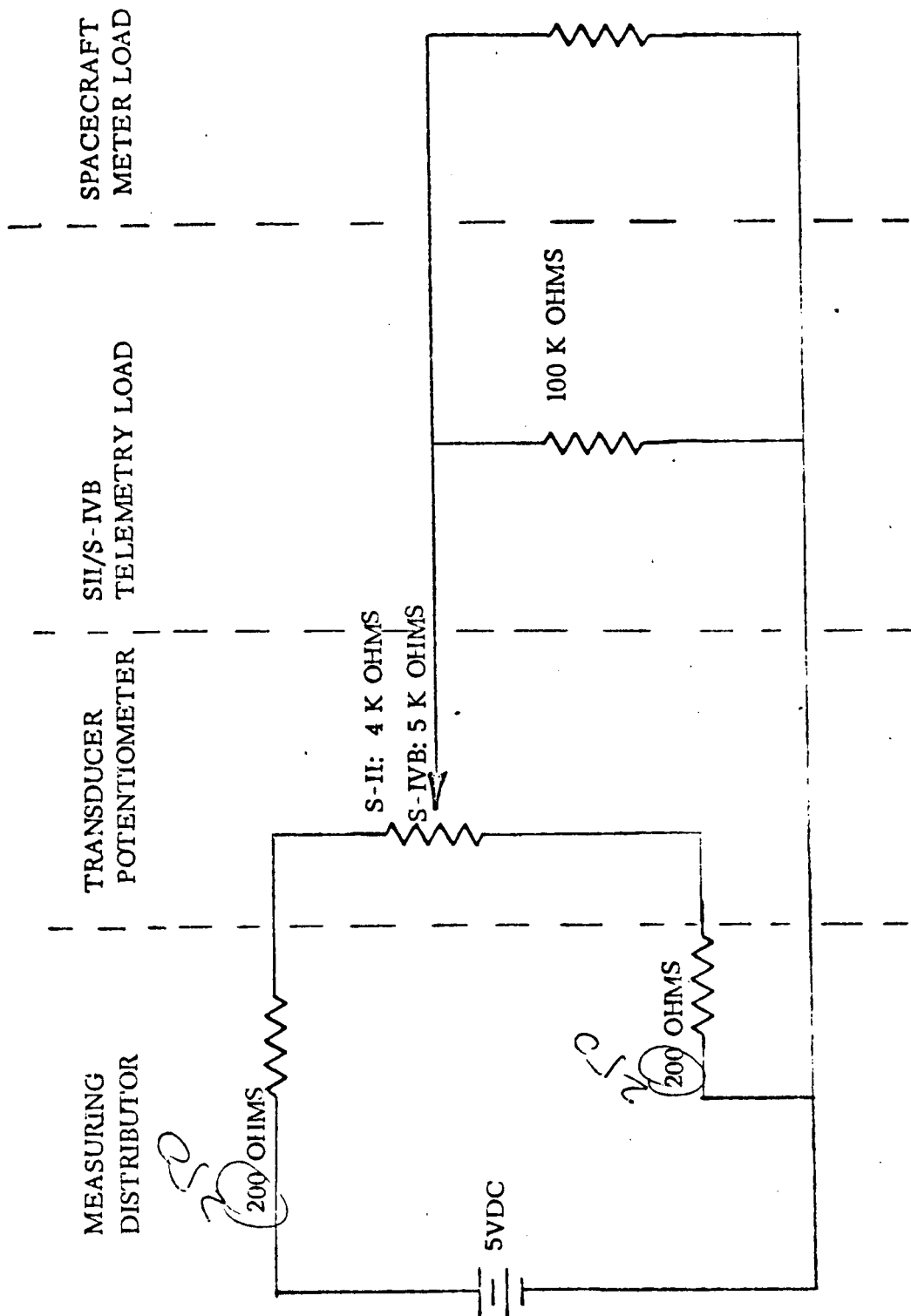
Voltage Range	0-5 volts
Source Impedance	1356 ohms (maximum)
Load Impedance	78,920
Zero Offset	0.405 volts
Scale Factor	0.08484 volts per psi

The values shown are nominal, since all the resistance values have tolerances, particularly the transducer total resistance and end point resistance.

The 250 ohm bias resistors shown for the S-IVB transducers are the values actually specified at present according to Mr. Snields, R-ASTR-EA. However, the value of this resistance is planned to be discussed at the next meeting of the EDS Design Subpanel which is scheduled for late May or early June. When a final decision is reached, the ICD's should be revised accordingly.

James C. Derington
5/17/66

R-ASTR-EA 876-307.



ENCLOSURE #1

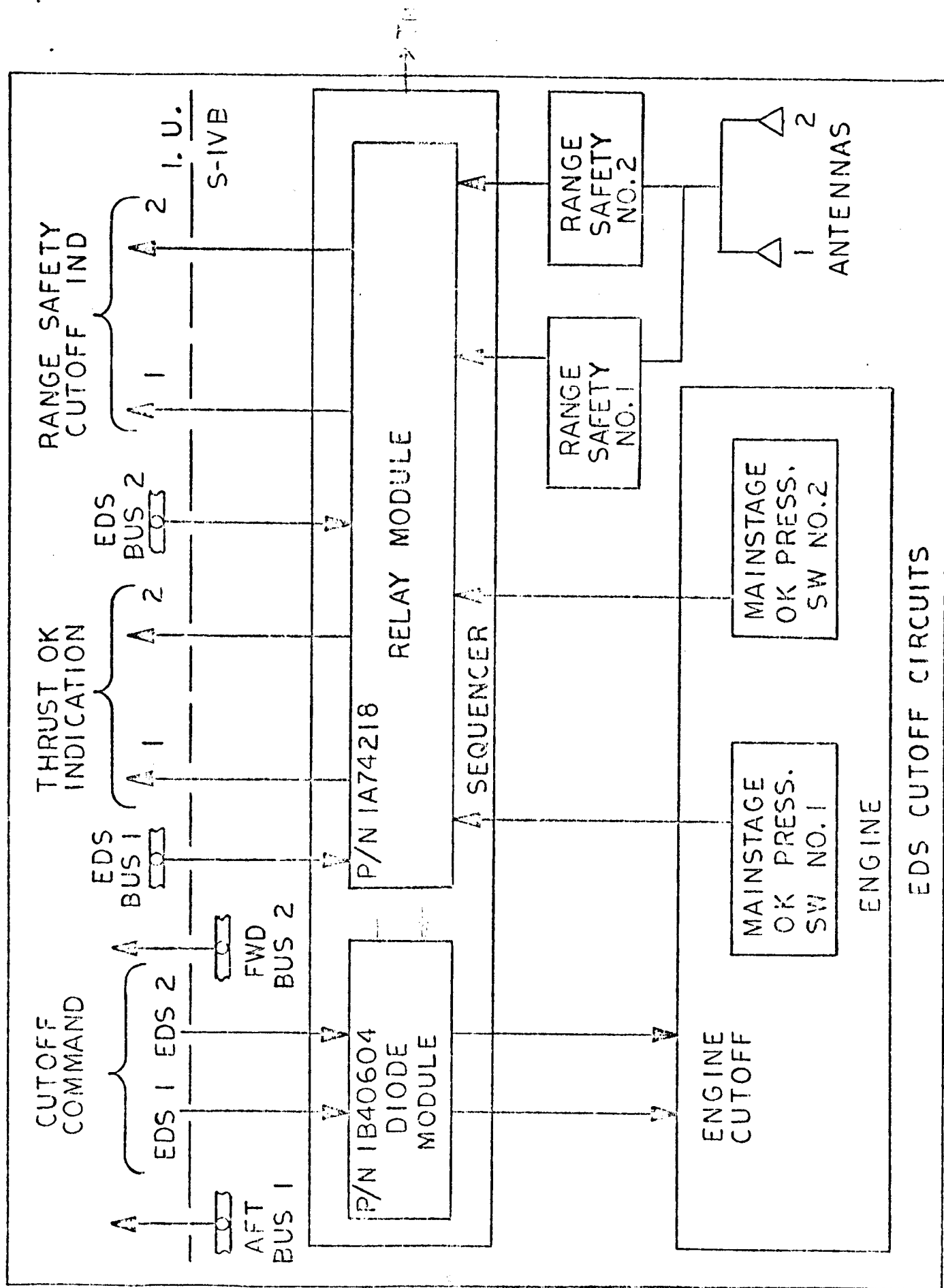
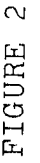


FIGURE 1

PD EEW FIRING UNIT
ARM & ENG CUTOFF
COM ON IND



- EDS MEASUREMENTS -

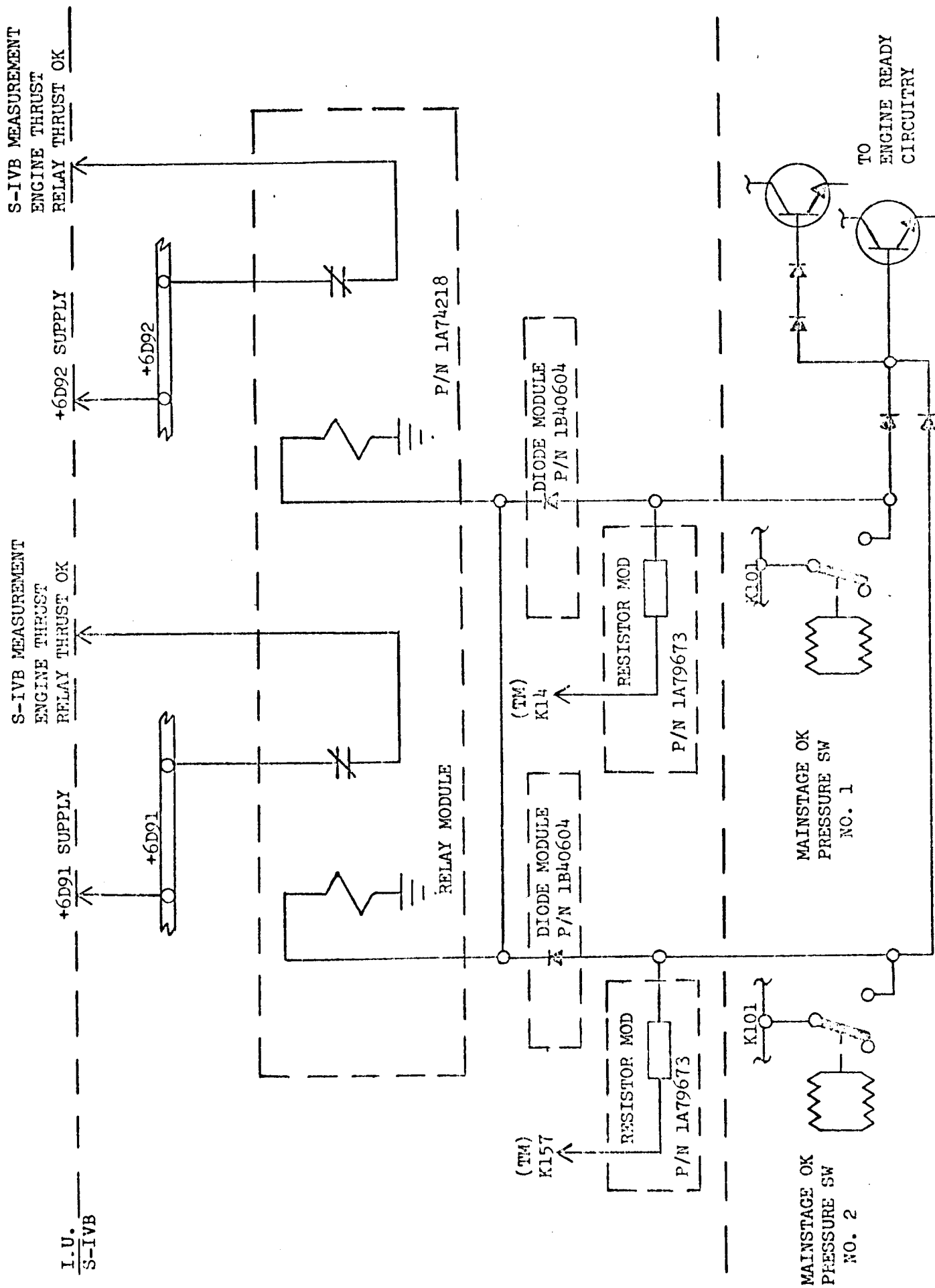


FIGURE 3

EDS ULLAGE PRESSURE MEASUREMENTS

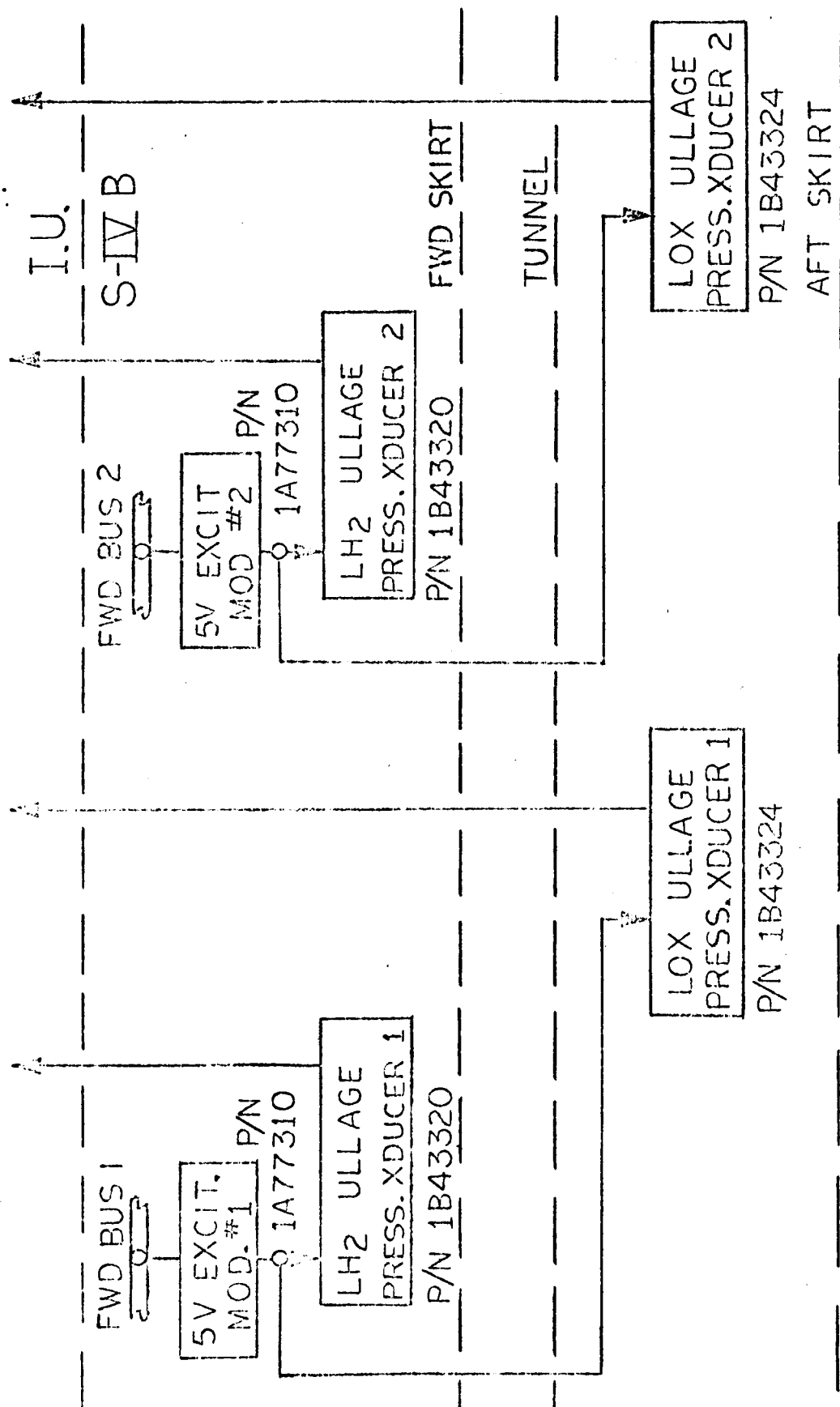


FIGURE 4

EDS ULLAGE PRESSURE - MEASUREMENTS

I.U. MEASUREMENTS
LOX ULLAGE PRESSURE

XDUCER NO. 1

XDUCER NO. 2

I.U. MEASUREMENTS
FUEL ULLAGE PRESSURE

XDUCER NO. 1

XDUCER NO. 2

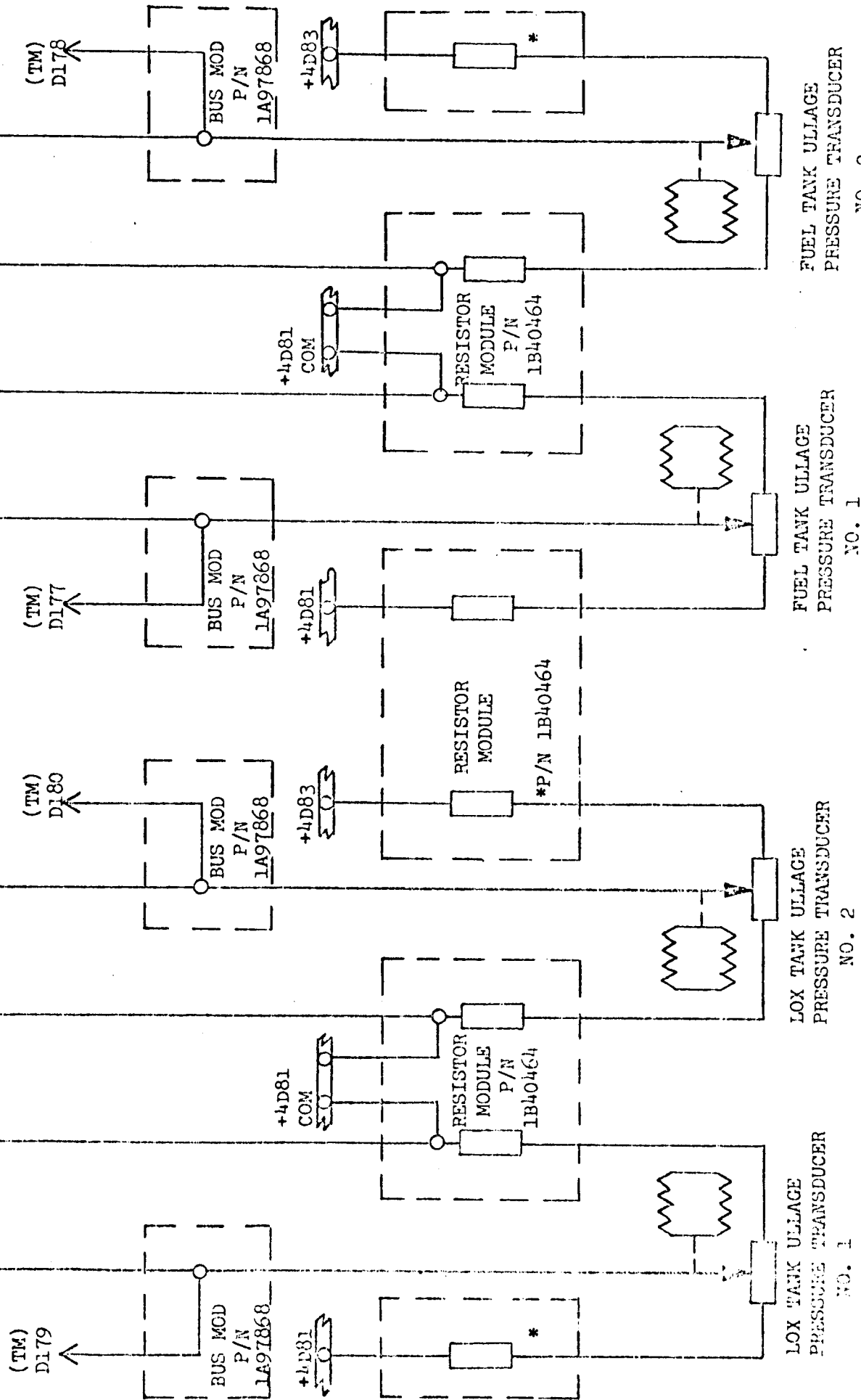


FIGURE 5

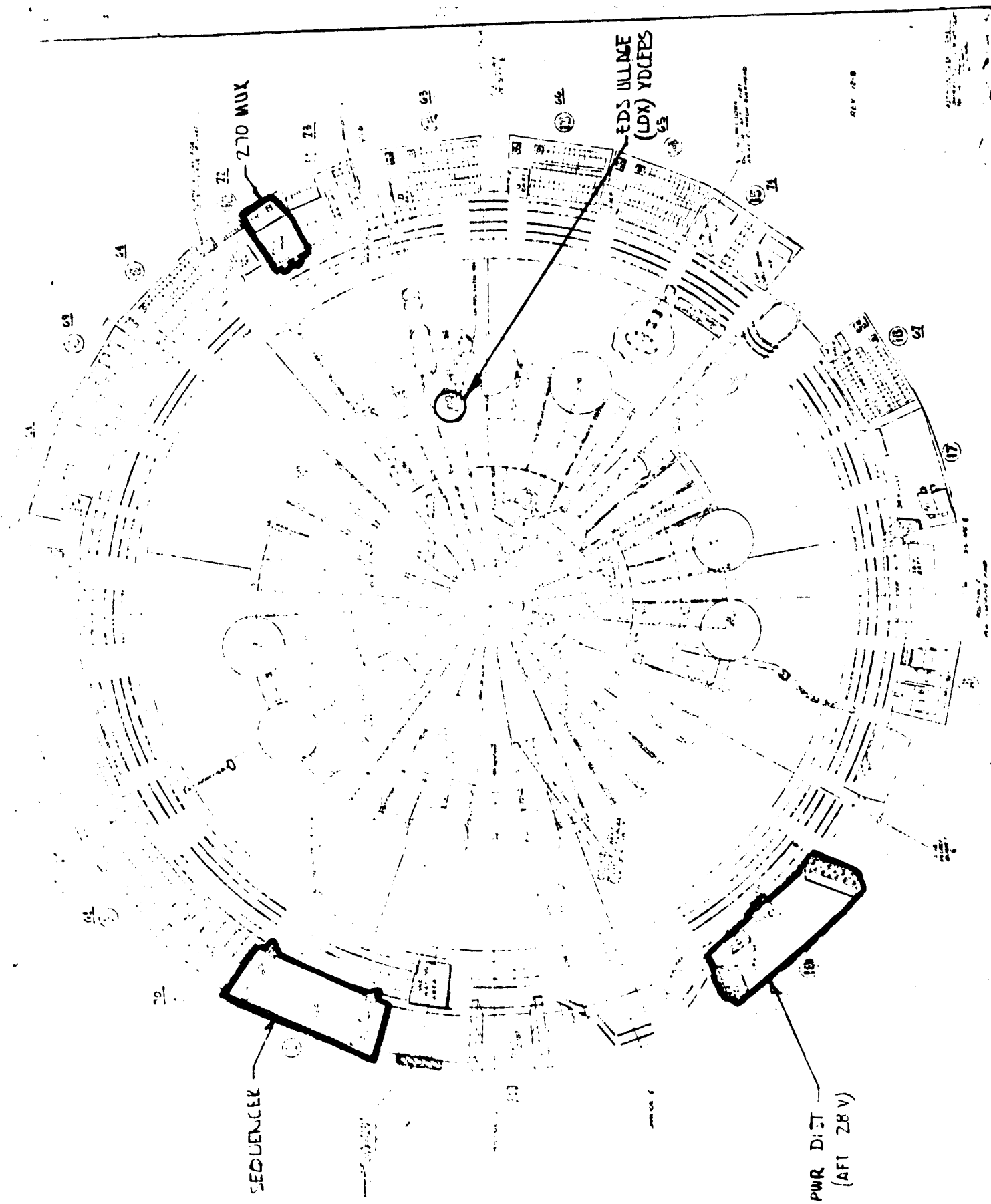


FIGURE 6

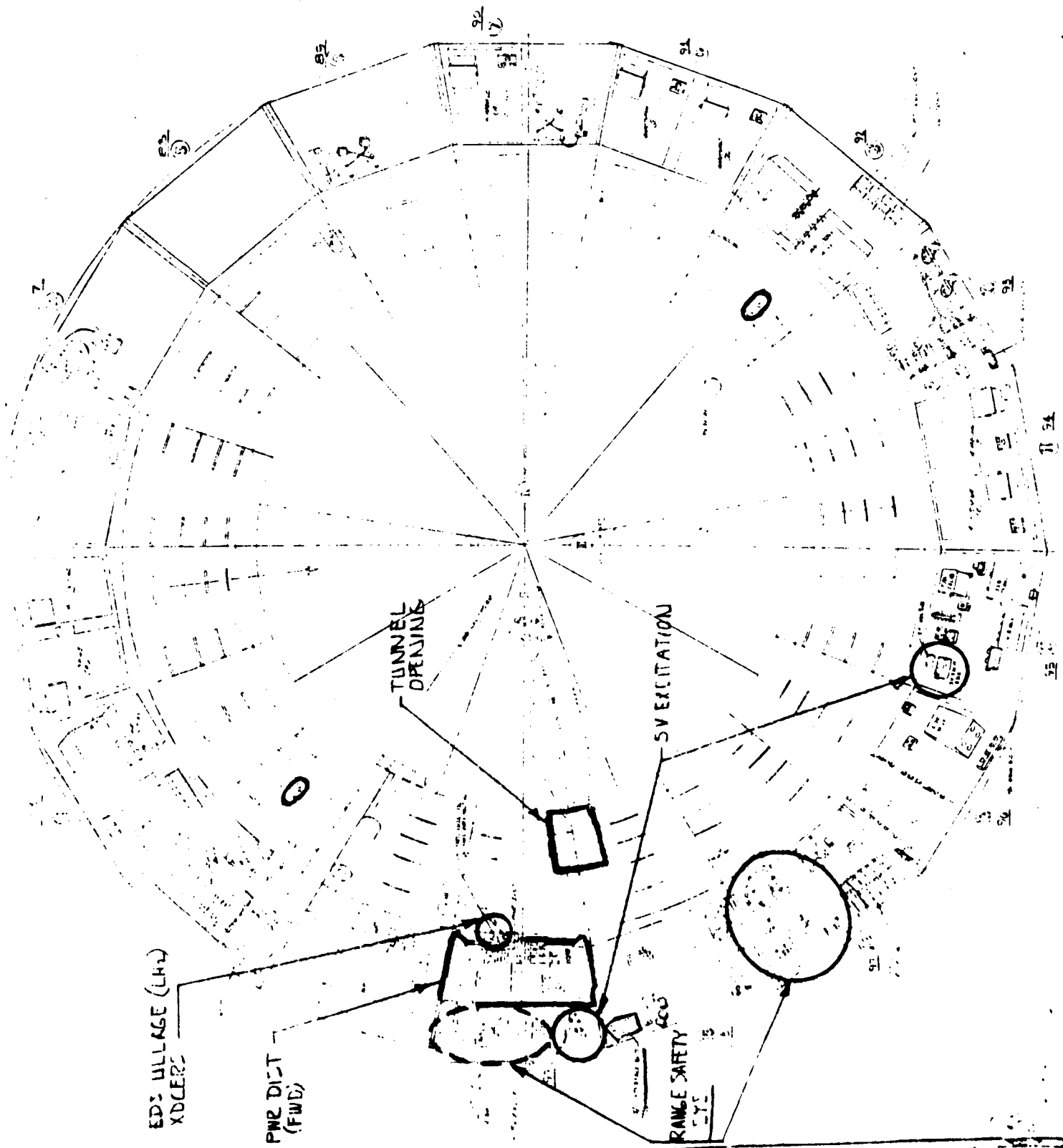
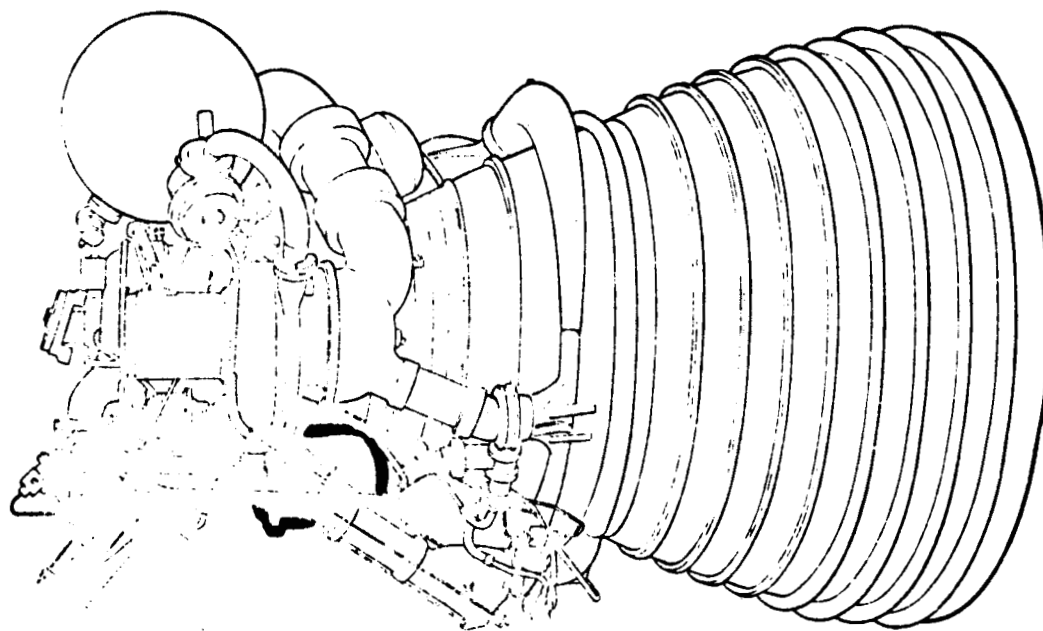
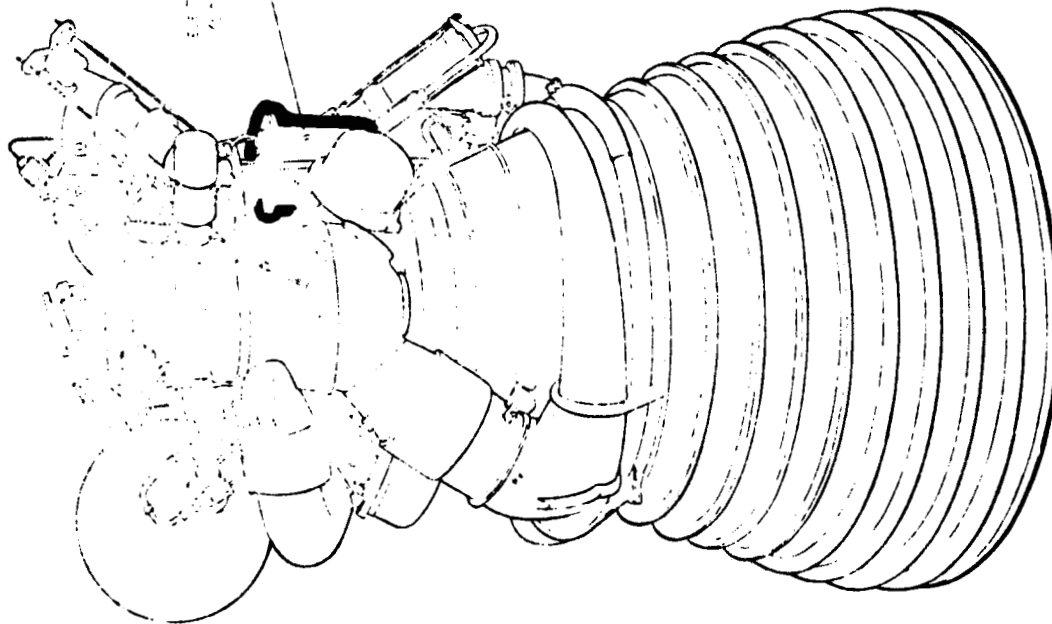


FIGURE 7



J2 ENGINE
RIGHT SIDE



J2 ENGINE
LEFT SIDE

PREPARED FOR NASA HEAD

THAN SOURCE: CALIF. DRAWING
SAUCER SEER

DOUGLAS
ENGINE COMPANY, INC. SANTA MONICA, CALIFORNIA

CODE IDENT NO. 101558

0

SCALE

SHEET 2

FIGURE 8